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LISTS OF SPECIES

Frogs and toads of the Pedra Azul–Forno Grande Biodiversity Corridor, southeastern Brazil

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ABSTRACT: We conducted a long-term amphibian survey at the biodiversity corridor Pedra Azul-Forno Grande, in the mountain region of the state of Espírito Santo, Brazil. Sampling was conducted from April 2004 to October 2009 and we registered 43 species. Two species (*Dendropsophus ruschii* and *Megaelosia apuana*) are included in the state list of threatened species and *Scinax belloni* is included in the IUCN/GAA list. We provide color photographs for most species found in the region.

INTRODUCTION

Despite intensive alteration of its habitats, due to logging, urbanization, intensive farming and other uses, the Atlantic Rainforest still harbors a significant fraction of the World's biological diversity (Morellato and Haddad 2000). The biome is also house to a great number of endemic species; around 6000 vascular plants and 550 terrestrial vertebrates (Myers *et al.* 2000). At least 80 of the over 400 frog species found in the Atlantic Rainforest are endemic to the biome (Silvano and Pimenta 2003; Haddad *et al.* 2008).

The state of Espírito Santo, Brazil, was totally covered by Atlantic Rainforest prior to European colonization. Although there is a considerable portion of the habitat already destroyed in the state, it still comprises a great realm for biodiversity. Species diversity is astonishing and a large number of endemic taxa are present, including vertebrates, invertebrates and plants (Almeida *et al.* 2011, Simon *et al.* 2005; Moreira *et al.* 2008, Brown and Freitas 2000, Thomaz and Monteiro 1997). Furthermore, of the 133 species of amphibians listed for Espírito Santo, sixteen are endemic to the state, six of which only known from their type-localities (Almeida *et al.* 2011). Here we provide a species list for the frog and toad species (Anura) in the biodiversity corridor Pedra Azul–Forno Grande, a highly fragmented Atlantic Rainforest remnant in the mountain region Espírito Santo. We also briefly discuss amphibian diversity in the state, comparing our results to those from published lists.

MATERIAL AND METHODS

Study area

Connectivity routes linking two or more forest fragments are commonly named "ecological" or "biodiversity" corridors. We sampled a region known as Corredor Ecológico Pedra Azul–Forno Grande (*Pedra Azul–Forno Grande Biodiversity Corridor* [from now on PA-FG], Figure 1). The entire region of PA-FG is part of the Atlantic Rainforest biome. The area is located in the mountain region of Espírito Santo, across the municipalities of Alfredo Chaves, Castelo, Domingos Martins, and Vargem Alta, and comprises the protected areas Parque Estadual de Pedra Azul (PEPAZ; Figure 2A) and Parque Estadual do Forno Grande (PEFG; Figure 2B), and several patches of forest with distinct degrees of preservation, but not inserted in any protected area. PEPAZ is located in the

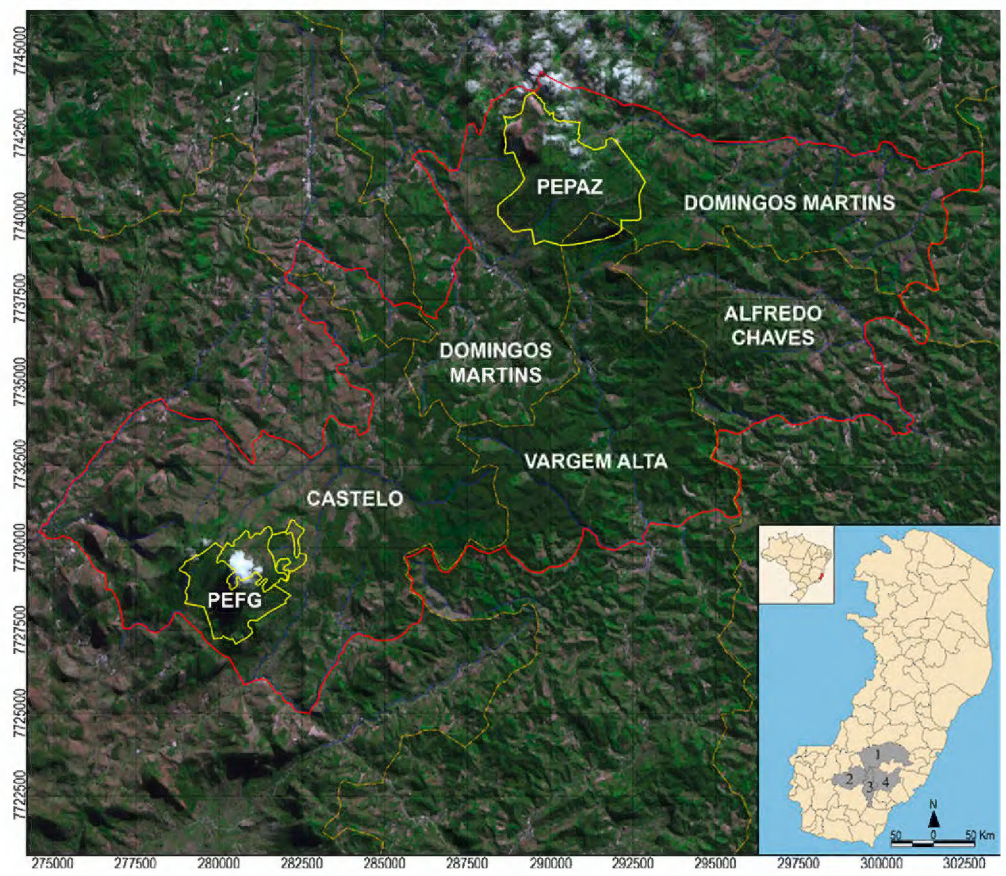

FIGURE 1. Satellite image of Pedra Azul–Forno Grande Biodiversity Corridor, outlined in red, in the state of Espírito Santo. The municipalities of Domingos Martins, Castelo, Vargem Alta, and Alfredo Chaves are outlined in dashed yellow line. Limits of Parque Estadual do Forno Grande (PEFG) and Parque Estadual de Pedra Azul (PEPAZ) are outlined in hard yellow lines. Figure adapted from an unpublished report by Cepemar Meio Ambiente.

Municipality of Domingos Martins (~ 20°24' S, 41°01' W; 1240 ha) and PEFG is located in the Municipality of Castelo (~ 20°31' S, 41°07' W; 730 ha). Coldest months are from May to September (driest months from April to September), with the raining season extending from November to January. The altitudinal range inside PEPAZ is 960-1910m and PEFG is 1200-2039m. Vegetation in the region is composed predominantly by Tropical rain forest but several areas have been heavily logged, or even completely cut for the opening of pastures or agriculture (evident in Figures 2A, B, E). A plethora of breeding sites for amphibians are available, including several small streams and natural temporary ponds (Figure 2C, D). Human made, temporary and permanent, ponds are also common in the region (Figure 2E) and serve as breeding and foraging sites for many species. Within both protected areas (PEPAZ and PEFG) large rock outcrops are present (Figures 2A, B), and herbaceous to shrubby vegetation is common. Many large bromeliads (*e.g. Alcantharea*) are found over the rocks (Figure 2F), but epiphytic species are also found inside forests (the latter have been largely harvested; our personal observation). Several species were found within bromeliads, using them either as breeding sites or for shelter and foraging.

Sampling

We surveyed PA-FG from September 2004 to October 2009, using visual and audio surveys, as described in Heyer *et al.* (1994). Sampling was more intense inside the protected areas and its immediate vicinities, but we also collected in several sites along the forest remnants that link the two parks. The list was compiled from several distinct projects we held on the region along the years, and sampling effort was not equal among regions and therefore cannot be exactly quantified, except from a few time intervals. Photographs of at least one individual of every species were taken in the field, during this study, unless noted otherwise. Species not photographed in PA-

Figure 2. Localities and habitats surveyed for amphibians in Pedra Azul. (A) General view of the Pedra Azul region, with the actual Pedra Azul rock at the back. (B) General view of the Forno Grande region. (C) Small stream and a temporary pond inside the forest in Pedra Azul. (D) Temporary pond formed in an open area on the forest edge. (E) Permanent pond in an anthropic clearing. (F) Bromeliads attached to rocky outcrops in Forno Grande.

FA are illustrated by specimens from nearby localities.

To complement the list, we surveyed zoological collections with large holdings of specimens from Espírito Santo. Voucher specimens are deposited in the following institutions: Coleção de Anfíbios Célio F. B. Haddad, Universidade Estadual Paulista, Rio Claro, São Paulo (CFBH); Museu de Biologia Professor Mello Leitão, Santa Teresa, Espírito Santo (MBML); Museu Nacional, Rio de Janeiro (MNRJ); Museu de Zoologia João Moojen, Universidade Federal de Viçosa, Minas Gerais (MZUFV); Coleção de Anfíbios do Instituto de Biologia da Universidade Federal do Rio de Janeiro (ZUFRJ), and are listed in Appendix 1. Taxonomy followed Frost (2011). Collection permits were issued by IBAMA (054/05 – IBAMA/RAN, process 02001.002792/98-03; 045/06 – IBAMA-ES; 80/07-NUFAUNA/NUPESCA/DITEC, process 02009.001714/2006; 16915 –ICMBio/SISBIO).

Results and Discussion

We registered 43 species, representing nine families, in the PA-FG (Table 1, Figures 3-10, Appendix 1). The list of amphibians threatened with extinction in the state of Espírito Santo includes 10 species (Gasparini *et al.* 2007), two of which we found in our study area: *Dendropsophus ruschii* and *Megaelosia apuana.* Both species have, however, been found in streams inside forest or on forest edges in other regions (Cassini *et al.* 2007, Almeida *et al.* 2011; Santos *et al.* 2011). In PA-FG we have found apparently healthy populations of both *D. ruschii* and *M. apuana.* Several calling males, amplectant pairs, egg clutches, tadpoles and juveniles of *D. ruschii* (Figure 3A-B) were found in consecutive years since the discovery of the population in 2005 (Peloso and Gasparini 2006). We did not observe reproductive behavior of *M. apuana*, but the finding of large tadpoles and recently metamorphosed juveniles (Figure 3C) evidences that reproduction is taking place. Furthermore, *Scinax belloni* (Figure 8B) – considered as *Endangered* in the IUCN Red List of Threatened Species (IUCN 2011) – was recorded both in PEFG and in the fragments between PEPAZ and PEFG.

Published amphibian inventories for the Espírito Santo are scant and generally based on rapid inventories (but see Tonini *et al.* 2010). In a recent work Almeida *et al.* (2011) recorded 133 amphibian species occurring in the state. Species diversity found in PA-FG is similar to other mountain regions in the state of Espírito Santo. Ramos and Gasparini (2004) found 41 species in the Goiapaba-Açu region, municipality of Fundão, and Tonini *et al.* (2010) found 52 species in the Reserva Biológica de Duas Bocas, municipality of Cariacica. Rödder *et al.* (2007) briefly commented on anuran diversity in scattered locations in the municipality of Santa Teresa and adjacent localities. The authors listed 54 species for Estação Biológica de Santa Lúcia, 21 for Pousada Paradiso, 30 for Reserva Biológica de Nova Lombardia, and 23 for Vargem Alta.

Recent data on the diversity of amphibians in the state of Espírito Santo, together with recent findings of new species of frogs in the state (*e.g.* Pombal *et al.* 2003; Caramaschi *et al.* 2004, Napoli 2005, Pombal and Gasparini 2006, Caramaschi *et al.* 2009, Faivovich *et al.* 2010, Canedo and Pimenta 2010) reinforces the importance of additional biodiversity surveys in the state, even in previously studied areas, as is the case of Pedra Azul, studied by many herpetologists for many decades (our personal observation), but for which no published species list is available.

The species list of PA-FG will probably grow when additional techniques are used. The use of pitfall traps

Figure 3. Species found during this study that are included in the list of threatened species of Espírito Santo: *Dendropsophus ruschii*: (A) egg clutch deposited on a pending leaf above water and (B) juvenile. *Megaelosia apuana*: (C) juvenile.

may render the collection of additional leaf-litter frogs (Terrarana and Cycloramphidae), which are of difficult collection and observation in visual surveys. As a good example, during recent fieldwork in Duas Bocas, Tonini *et al.* (2010) found 52 species, 18 more species than an inventory published few years before (Prado and Pombal 2005). Several of the additional records found by Tonini *et al.* (2010) were representatives of terrestrial secretive species, most likely only sampled because of the use of traps. Even without additional techniques (*e.g.* pitfall traps), our inventory attained a considerable number of species.

Conservation of biodiversity corridors is crucial for maintaining genetic diversity of populations present in fragments. Dixo *et al.* (2009) evaluated the reduction of genetic diversity in populations of *Rhinella ornata* and connectivity among fragmented habitats, comparing medium and small forest fragments, connected or not to forest areas through corridors. Their work shows that the fragment size is positively correlated with genetic diversity, posing a problem for smaller populations, where genetic variability is smaller (Dixo *et al.* 2009). Biodiversity corridors should then be preserved and protected, and new ones must be implemented in the Atlantic Rainforest, to make up for its fragmented landscape. The presence of unique species in the forest fragments (nine species, see Table 1) that connect PEPAZ and PEFG and the occurrence of threatened species in this region reinforce the importance of conservation of this biodiversity corridor.

Figure 4. Some of the frog species from Pedra Azul-Forno Grande: (A) *Brachycephalus alipioi*; (B) *Ischnocnema abdita*; (C) *Ischnocnema guenteri*; (D) *Ischnocnema oea*, specimen from Santa Teresa, ES; (E) *Ischnocnema verrucosa*, specimen from Duas Bocas, ES; (F) *Rhinella crucifer*.

Figure 5. Some of the frog species from Pedra Azul-Forno Grande: (A) *Haddadus binotatus*; (B) *Crossodactylodes* cf. *bokermanni*; (C) *Proceratophrys boiei*; (D) *Proceratophrys moehringi*, specimen from Santa Teresa, ES (Photo by: J. E. Simon); (E) *Proceratophrys schirchii*; (F) *Thoropa miliaris*. (G) *Flectonotus fissilis*; (H) *Aplastodiscus arildae*.

Figure 6. Some of the frog species from Pedra Azul-Forno Grande: (A) *Aplastodiscus cavicola*; (B) *Bokermannohyla caramaschii*; (C) *Bokermannohyla ibitipoca*; (D) *Dendropsophus decipiens*; (E) *Dendropsophus elegans*; (F) *Dendropsophus microps*; (G) *Dendropsophus minutus*; (H) *Dendropsophus ruschii*.

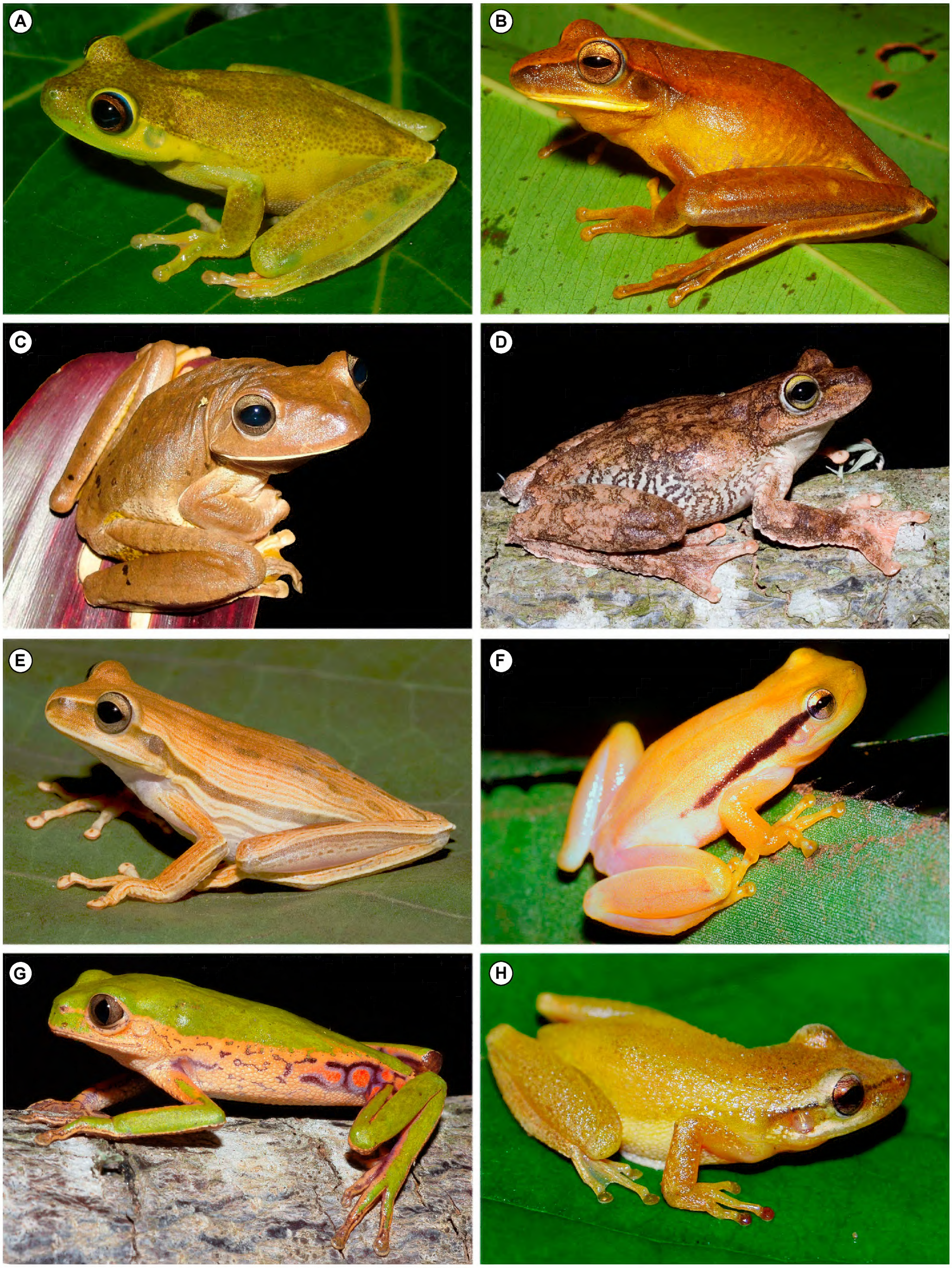

FIGURE 7. Some of the frog species from Pedra Azul-Forno Grande: (A) *Hypsiboas albomarginatus*, specimen from Guarapari, ES; (B) *Hypsiboas albopunctatus*; (C) *Hypsiboas faber*; (D) *Hypsiboas pardalis*; (E) *Hypsiboas polytaenius*; (F) *Phyllodytes kautskyi*; (G) *Phyllomedusa rohdei*; (H) *Scinax alter*.

FIGURE 8. Some of the frog species from Pedra Azul-Forno Grande: (A) *Scinax* cf. *arduous*, specimen of Santa Teresa, ES; (B) *Scinax belloni*; (C) *Scinax fuscovarius*; (D) *Scinax hayii*; (E) *Scinax heyeri*; (F) *Scinax kautskyi*; (G) *Scinax* sp. (gr. *ruber*); (H) *Megaelosia apuana*.

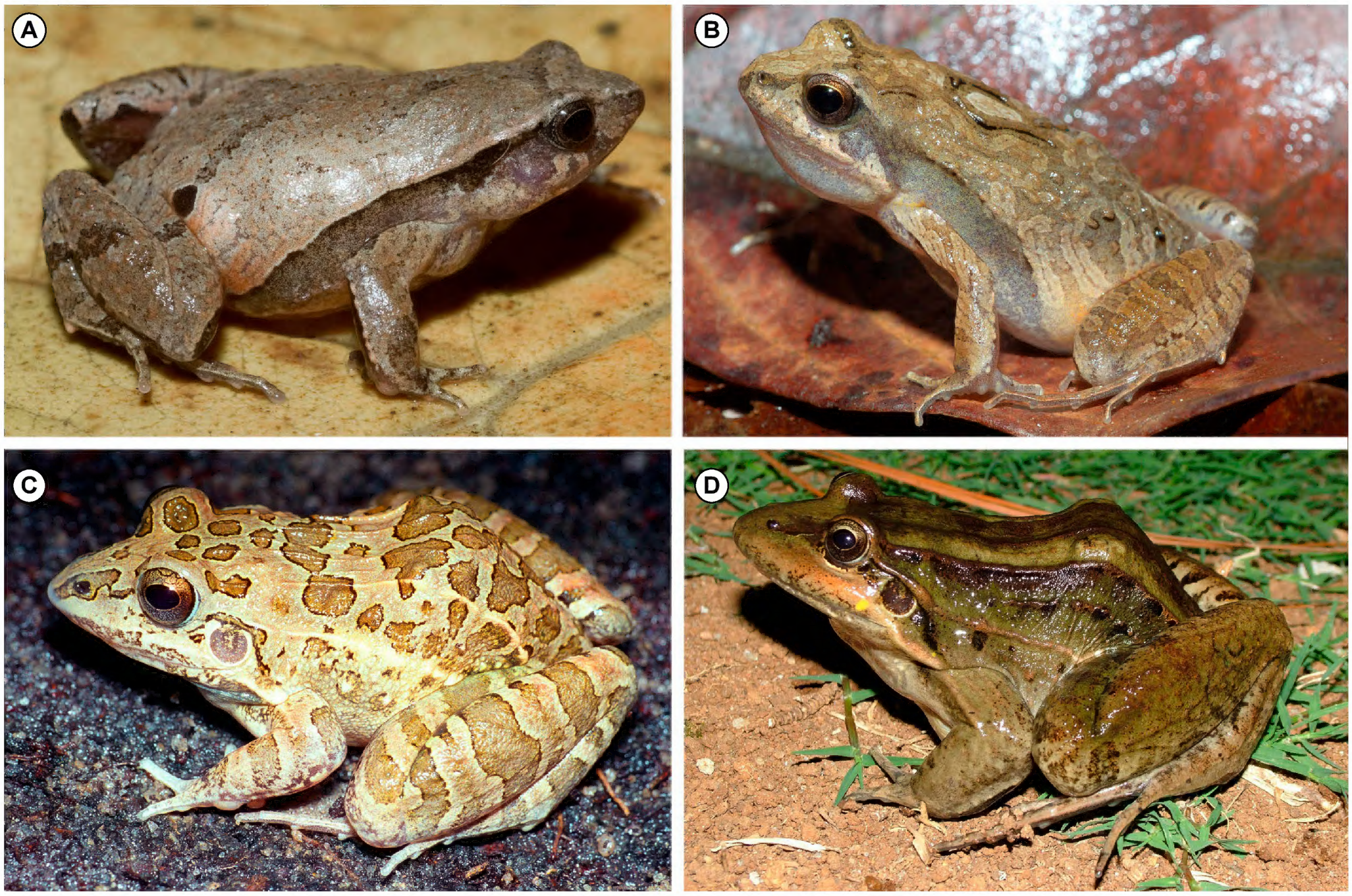

Figure 9. Some of the frog species from Pedra Azul-Forno Grande: (A) *Physalaemus crombiei*; (B) *Physalaemus cuvieri*; (C) *Leptodactylus fuscus*, specimen from Santa Teresa, ES; (D) *Leptodactylus latrans*.

Table 1. List of species found in the Pedra Azul-Forno Grande Biodiversity Corridor, state of Espírito Santo, Brazil. The sampling method can be Species marked with an asterisk were found exclusively during examination of collections material and were not collected during our study. Sampling Methods; A = adult, T = tadpole, V = vocalizations, PA = Parque Estadual da Pedra Azul, FG = Parque Estadual do Forno Grande, Fr = Forest fragments: any specimen collected outside the parks but within the biodiversity corridor PA-FG.

TAXON	METHOD	PA	FG	FR.
Brachycephalidae				
Brachycephalus alipioi Pombal and Gasparini 2006 (Fig. 4A)	A	X		X
Ischnocnema abdita Canedo and Pimenta 2010 (Fig. 4B)	A		X	X
Ischnocnema guentheri (Steindachner 1864) (Fig. 4C)	A/V	X	X	X
Ischnocnema oea (Heyer 1984) (Fig. 4D)	A	X	X	
Ischnocnema verrucosa (Reinhardt and Lütken 1862) (Fig. 4E)	A		X	
Bufonidae				
Rhinella crucifer (Wied-Neuwied 1821) (Fig. 4F)	A/T/V	X	X	X
Craugastoridae				
Haddadus binotatus (Spix 1824) (Fig. 5A)	A	X	X	X
Cycloramphidae				
Crossodactylodes cf. *bokermanni* Peixoto 1983 (Fig. 5B)	A			X
Proceratophrys boiei (Wied-Neuwied 1825) (Fig. 5C)	A/T/V	X	X	X
**Proceratophrys moehringi* Weygoldt and Peixoto 1985 (Fig. 5D)	A			X
**Proceratophrys phyllostoma* Izecksohn, Cruz and Peixoto 1999	A			X
Proceratophrys schirchi (Miranda-Ribeiro 1937) (Fig. 5E)	A	X		
Thoropa miliaris (Spix 1824) (Fig. 5F)	A/T/V	X	X	X
Hemiphractidae				
Flectonotus fissilis Bokermann 1966 (Fig. 5G)	A	X		
Hylidae				
Aplastodiscus arildae (Cruz and Peixoto 1987) (Fig. 5H)	A/T/V	X	X	X
Aplastodiscus cavicola (Cruz and Peixoto 1985 "1984") (Fig. 6A)	A/V	X		X
Bokermannohyla caramaschii (Napoli 2005) (Fig. 6B)	A/V		X	X
Bokermannohyla ibitipoca (Caramaschi and Feio 1990) (Fig. 6C)	A/V	X	X	

Table 1. ***Continued***.

TAXON	METHOD	PA	FG	FR.
Dendropsophus decipiens (Lutz 1925) (Fig. 6D)	A	X		X
Dendropsophus elegans (Wied-Neuwied 1824) (Fig. 6E)	A/V	X		X
Dendropsophus microps (Peters 1872) (Fig. 6F)	A			X
Dendropsophus minutus (Peters 1872) (Fig. 6G)	A/T/V	X	X	X
Dendropsophus ruschii (Weygoldt and Peixoto 1987) (Fig. 6H)	A/T/V	X		X
Hypsiboas albomarginatus (Spix 1824) (Fig. 7A)	A	X		X
Hypsiboas albopunctatus (Spix 1824) (Fig. 7B)	A/V	X		X
Hypsiboas faber (Wied-Neuwied 1821) (Fig. 7C)	A/T/V	X		X
Hypsiboas pardalis (Spix 1824) (Fig. 7D)	A/T/V	X	X	X
Hypsiboas polytaenius (Cope 1870) (Fig. 7E)	A/T/V	X	X	X
Phyllodytes kautskyi Peixotoand Cruz 1988 (Fig. 7F)	A			X
Phyllomedusa rohdei Mertens 1926 (Fig. 7G)	A/T/V	X	X	X
Scinax alter (B. Lutz 1973) (Fig. 7H)	A/V		X	
**Scinax* cf. *arduous* Peixoto 2002 (Fig. 8A)	A			X
Scinax belloni Faivovich, Haddad and Gasparini 2010 (Fig. 8B)	A/T/V		X	X
Scinax fuscovarius (A. Lutz 1925) (Fig. 8C)	A/V			X
Scinax hayii (Barbour 1909) (Fig. 8D)	A/V			X
Scinax heyeri (Peixoto andWeygoldt 1986) (Fig. 8E)	A		X	
Scinax kautskyi (Carvalho-e-Silva and Peixoto 1991) (Fig. 8F)	A			X
Scinax sp. (grupo *ruber*) (Fig. 8G)	A/T/V	X	X	X
Hylodidae				
Megaelosia apuana Pombal, Prado and Canedo 2003 (Fig. 8H)	A/T	X		X
Leiuperidae				
Physalaemus crombiei Heyerand Wolf 1989 (Fig. 9A)	A/T/V		X	X
Physalaemus cuvieri (Fitzinger 1826) (Fig. 9B)	A/V			X
Leptodactylidae				
Leptodactylus fuscus (Schneider 1799) (Fig. 9C)	V	X	X	X
Leptodactylus latrans (Linnaeus 1758) (Fig. 9D)	A	X		X

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Appendix 1. Voucher specimens.

Aplastodiscus arildae (CFBH 10842, 22839, MZUFV 5219); *Aplastodicsus cavicola* (CFBH 23197, 25543-46); *Bokermannohyla caramaschii* (CFBH 10843, 22845-46, MZUFV 5222); *Bokermannohyla ibitipoca* (MZUFV 5220-21); *Brachycephalus alipioi* (CFBH 19622, 24667, MBML 2850); *Crossodactylodes bokermanni* (MBML 16); *Dendropsophus decipiens* (MBML 6779); *Dendropsophus elegans* (CFBH 22837); *Dendropsophus microps* (CFBH 26971-73); *Dendropsophus minutus* (CFBH 4080-82, MBML 6632-34); *Dendropsophus ruschii* (CFBH 9607, 10852-54, MBML 6669-6670); *Flectonotus fissilis* (MZUFV 5226-27, MBML 7235); *Haddadus binotatus* (CFBH 18435-36, 18452-54, MNRJ 26150); *Hypsiboas albomarginatus* (MNRJ 34137); *Hypsiboas albopunctatus* (MBML 1630); *Hypsiboas faber* (MBML 6532-34); *Hypsiboas pardalis* (CFBH 22843, MZUFV 5228); *Hypsiboas polytaenius* (CFBH 22838); *Ischnocnema abdita* (CFBH 27008-10); *Ischnocnema guenteri* (CFBH 22842); *Ischnocnema oea* (CFBH 27013); *Ischnocnema verrucosa* (MBML 7279); *Leptodactylus latrans* (http://calphotos.berkeley.edu/; photo ID 0511 1754); *Megaelosia apuana* (CFBH 10811, MNRJ 26057); *Phyllodytes kautskyi* (MBML 2570); *Phyllomedusa rohdei* (CFBH 10846, 10872); *Physalaemus crombiei* (CFBH 26337); *Physalaemus cuvieri* (MBML 1629, CFBH 22840); *Proceratophrys boiei* (CFBH 10844, 10870-71, 19624, 22844); *Proceratophrys moehringi* (ZUFRJ 6198); *Proceratophrys phyllostoma* (MBML 325; 1151); *Proceratophrys schirchi* (MBML 7369-70); *Rhinella crucifer* (MNRJ 26158); *Scinax alter* (MBML 1534-36); *Scinax* cf. *arduous* (MBML 7289); *Scinax belloni* (CFBH 9733, 18281-85); *Scinax fuscovarius* (MBML 7283-84); *Scinax hayii* (CFBH 26967-70); *Scinax heyeri* (CFBH 25317); *Scinax kautskyi* (CFBH 10851); *Scinax* sp. (grupo *ruber*) (MBML 6639); *Thoropa miliaris* (CFBH 18430-34, 22841, 22847, MZUFV 5223-25).